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(54) **Thick optical element having a variable curvature**

(57) The optical element comprises a stack of at least two piezoelectric bimorph structures 1, 10, preferably identical, connected so as to deform in the same manner upon energisation, adjacent structures being spaced by elastic material 14, e.g. an elastomer, adhesive or weld, having a tensile strength which is low relative to that of the elements constituting the bimorph structures of piezoelectric material. As shown, a reflecting layer 5 is provided. The arrangement enables stable curvatures to be provided over a large area due to the thickness of the stack while retaining the degree of curvature associated with a single bimorph structure 1.

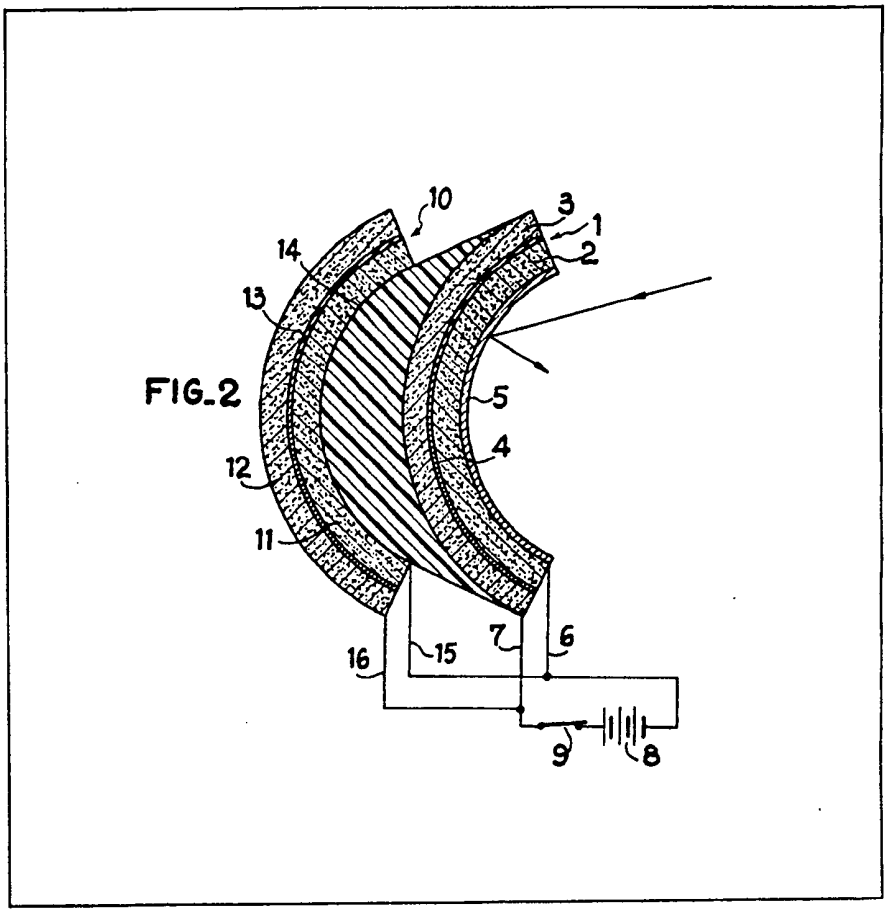

FIG_2

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SPECIFICATION

Thick optical element having a variable curvature

The present invention relates to optical elements having a variable curvature made from piezoelectric ceramic bimorph structures.

Such optical elements, and the optical systems of which they are part, have been disclosed in French patent applications No 77 12 799, 77 12 800, 77 12 901, 78 13 355 and 78 09 152 of which the Applicant is the proprietor.

Bimorph structures of ceramic material which are part of the construction of these elements and optical systems are made from thin piezoelectric ceramic elements so that their overall thickness is of the order of 1 mm.

As soon as the area of such bimorph structures exceeds certain limits, the bimorph structures, then also called bimorph plate structures, become subject to deformations which are difficult to avoid and create machining difficulties.

It is moreover not easy to control with precision the modifications of curvature of a thin element having a large area.

Consequently, the optical elements having a variable curvature produced up to the present time have relatively small areas, which constitutes a serious drawback in the case of, for example, mirrors.

An object of the invention is to overcome the aforementioned drawbacks and to provide an optical element having a variable curvature whose rigidity is sufficient to permit giving the desired area to the element without decreasing its curvature variation capability.

According to the invention there is provided an optical element having a variable curvature comprising a first bimorph structure, at least one of the components of which structure is made from a piezoelectric material, and electrodes for supplying current to said bimorph structure, wherein there is further provided at least one reinforcing piezoelectric bimorph structure provided with supply electrodes respectively connected to the electrodes of the first bimorph structure, one element of which reinforcing bimorph structure being placed against a corresponding element of the first bimorph structure and fixed to the latter by means of a layer of elastic material having a tensile strength which is low relative to the tensile strength of the elements constituting the bimorph structures of piezoelectric material.

Further features of the invention will be apparent from the ensuing description.

In the drawing, given solely by way of example:

Figure 1 is a sectional view of an optical element according to the invention, in the non-excited state;

Figure 2 is a sectional view of the optical element of Figure 1 in the excited state.

In Figure 1, the invention is assumed to be applied to a mirror having a variable focal length.

This mirror comprises a first bimorph structure 1 consisting of two elements 2 and 3 of piezoelectric ceramic material which are assembled by means of a layer 4 of an adhesive material.

The free face of the element 2 carries a layer 5 of reflecting material.

Electrodes 6 and 7 enable a voltage to be connected across the elements 2 and 3 of the bimorph structure 1 from a source of dc voltage 8 connected in series with a switch 9.

In order to increase the mechanical stiffness of the optical element constructed in this way, a second reinforcing bimorph structure 10 consisting of two elements 11 and 12 of piezoelectric ceramic material interconnected by a layer 13 of adhesive material, is fixed against the free face of the element 3 of the first bimorph structure by means of a layer 14 having a low tensile strength. This material may be formed for example by an elastomer.

The elements 11 and 12 of the second bimorph structure 10 are also connected to the terminals of the source of voltage 8 through electrodes 15, 16.

The layer of material 14 may also be an adhesive, a weld or other material.

The electric connections between the source of voltage 8 and the elements of the bimorph structures 1 and 10 are produced in accordance with the directions of the polarizations in the ceramic materials of these elements.

The bimorph structures are associated in such manner that, under the effect of the voltage of the source 8, their concavities face in the same direction.

In order to achieve optimum performance, the bimorph structures 1 and 10 must be preferably identical.

Upon the application of the voltage of the source 8 across the bimorph structures 1 and 10, by the closure of the switch 9, the optical element assumes the shape shown in Figure 2. It will be understood that the thicknesses of the various components of the optical element have been exaggerated in order to render the illustration more clear.

It will be observed that the layer 14 of material having a low tensile strength only very slightly opposes the deformation of the bimorph structures 1 and 10, so that the first bimorph structure undergoes practically the same variations as if it were alone.

In the embodiment just described, the mirror having a variable focal length comprises two bimorph structures.

However, it will be understood that the number of bimorph structures united by layers of a material having a low tensile strength is not limited to two.

element of the reinforcing bimorph structure being placed against a corresponding element of the first bimorph structure and fixed thereto by a layer of elastic material having a tensile strength which is low relative to the tensile strength of the elements constituting the bimorph structures of piezoelectric material.

2. An element as claimed in claim 1, wherein said first bimorph structure and said at least one reinforcing bimorph structure are identical.

3. An element as claimed in claim 1 or 2, wherein the ratio between the tensile strength of the material of said connecting layer and the tensile strength of the material of the piezoelectric elements is between 10^{-1} and 10^{4}.

4. An element as claimed in any one of the preceding claims, wherein said material of low tensile strength is an elastomer, an adhesive or a weld.

5. An element as claimed in any one of the preceding claims, comprising a plurality of reinforcing bimorph structures connected to the first bimorph structure and to each other by connecting layers of a material having a tensile strength which is low relative to the tensile strength of the piezoelectric elements.

6. An optical element having a variable curvature, substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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